Selective Angiocardiography in Congenital Heart Disease

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• **Angiocardiography has come to be a highly specialized procedure and there are definite indications for doing it. In specific cases it offers clear-cut advantages.**

Technical improvements permit a single injection of a small amount of contrast substance.

Selective angiocardiography is advised where the particular detail of a certain region in the heart is desired.

THERE ARE FEWER indications for angiocardiography today than was anticipated in the years before general use of this procedure had become an actuality. Many communications still make note of the limitations of the method and of the risk associated with it. Therefore, it is only in cases of real necessity that the procedure is carried out. As with other procedures entailing hazards of morbidity or mortality, the possible harm must be weighed against the benefits to be gained. Serious progressive heart disease with the exact diagnosis not known and the final issue in doubt presents a situation for such a decision. If a defect is suspected, information confirming the clinical diagnosis and providing anatomical orientation is important, for a surgeon then can use new surgical techniques with more confidence and better chance of benefit to the patient. The site and extent of defects, particularly of stenosis; the size, number, and location of septal defects; whether or not there is overriding of the aorta; and distinction of overriding aorta from high septal defects—all these can be fairly precisely determined by angiographic studies.

In general, techniques of angiocardiography as described by Robb and Steinberg in 1937 have not been greatly changed since then. Variations in the types of film changer, cassette changer, injector and other mechanical devices have made the results more predictable but have not made the procedure simpler. The authors have used the conventional venous angiocardiography in less than one-fifth of the cases studied. Selective angiocardiography, first described by Chavez in 1947, has proved better.

Since nearly all persons undergoing angiocardiography as a preliminary to operation must have cardiac catheterization as well, the authors have made catheterization an integral part of preoperative study. It is carried out essentially as described by Cournand in 1941. A local anesthetic is used at the point at which the vessel is opened for insertion of the catheter, and a basal anesthetic is added for children. After adequate data on the blood at various positions have been obtained and injection of opaque material is to be done, the tip of the catheter is placed near the structure about which information is desired. In most instances it is left in the apex or midportion of the right ventricle. A single high-speed injection of the opaque material selected (usually 70 per cent Urokon®) quickly fills the area around the catheter tip and usually promptly fills the pulmonary vessels and the entire ventricle, outlining the apertures within the ventricle. The quantity of material injected varies with the size of the patient and the size of the chamber which is to be filled. The speed of the injection varies with the quantity which must be injected, the size of the catheter, and the pressure placed upon it. A mechanical injector of the Gidlund type gives an injection rate which can fill a chamber within a half second. In general, it is desirable to complete the injection in less than two seconds. Such speed is necessary particularly in the demonstration of interatrial septal defects. It is not quite so important if the pulse rate is slow and the ventricular outlets are the subjects of study. In most cases the authors use an injection pressure of 3 kg. per cm.^{2},* but experimentally have used up to 10 kg. per cm.^{2} of pressure without manifest changes in intracardiac pressure or in the pulse rate or heart action where the quantities used were not greater than the volume of the heart chamber into which the material was injected. Using high density material in as small a quantity as can reasonably serve permits study of both ends of the opacified blood column as it moves to the various chambers of the heart.

There has been much comment recently about the relative merits of high-speed film changing and

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*3 kg. per square centimeter of area of cross-section of the lumen of the catheter.

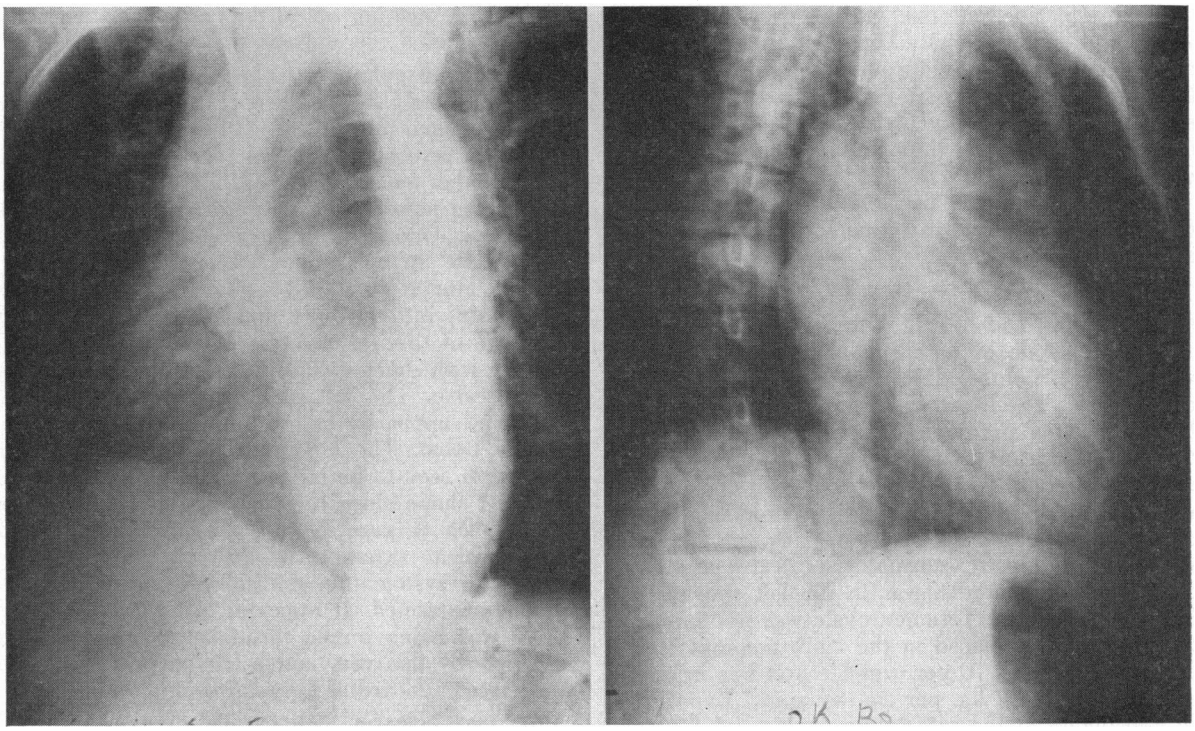

Figure 1 (Case 1).—Coarctation of the aorta. ***Left:*** **The aortic arch is seen in the left anterior oblique projection following injection of 40 cc. of 70 per cent Urokon into the superior vena cava. The length of the coarctation is seen here and in the simultaneous right anterior oblique projection** ***on the right.***

high-speed radiographic exposures. Each appears to have great advantage in certain circumstances, and both should be used in so far as possible. The shorter the exposure, of course, the better the detail obtained. The same is not necessarily true with regard to high speed changing of film or of cassettes, but it seems quite evident that since no one can know exactly when unusual events will take place within the heart, it is best to take many films in the hope of visualizing significant or characteristic changes. Thus cardiac functions are monitored not only by the roentgenograms obtained, but also by simultaneous electrocardiographic and respiratory curves on paper and on the oscilloscope in the room where the examination is taking place. As performed in the laboratory in which the authors work, selective angiocardiography is a highly cooperative procedure involving the synchronized efforts of nurse, technicians, anesthesiologists, cardiologists and radiologists. With this cooperative effort the accuracy of diagnosis has been better than 90 per cent and the incidence of complications slight. Transient arrhythmia, which was noted in about 30 per cent of the patients studied, was associated with the position of the catheter and the amount and type of medium injected. About one-fifth of the patients vomited. Nausea and vomiting are believed to have been contributory factors in the one case in which death occurred.

For purposes of illustration it might be well to report a case in which the angiocardiogram was normal. However there was no such case in the series of patients studied. The closest approximation was the following:

CASE 1. The patient was a 27-year-old, white male postal clerk who had been a mail carrier until he switched to his present job because of fatigue. He weighed approximately 160 pounds. The blood pressure was 170/90 mm. of mercury in the right arm and 150/86 mm. in the left. In the lower extremities the systolic pressure was 140 mm. on the right and 124 mm. on the left. The diastolic pressure was over 100 mm. on both sides. Since birth the patient had had a systolic murmur over the precordium and down the back. No popliteal or femoral pulse was obtainable. A diagnosis of coarctation of the aorta had been made. The heart was slightly large. Angiocardiography was performed with a catheter in the superior vena cava. Forty cubic centimeters of 70 per cent Urokon was injected, and the films were exposed at a rate of 2 per second for 12 seconds. The right atrium filled promptly and well. Our first film disclosed the opaque bolus passing through the right ventricle into the pulmonary artery. A second film showed the initial filling of the left atrium and of the left ventricle. The third (Figure 1) delineated the aorta quite nicely, with the coarctation sharply delimited. It was noted that the constricted segment was short and that the obstruction was incomplete. No extensive collateral vessels were seen. The ana-

tomical situation of the various chambers and valves was quite normal. The dilution and mixing of the blood as it passed through the lungs was fairly limited. The contribution of the cavae, however, and the mixing in the ventricle necessitated the use of a larger amount of the opaque media than might otherwise be necessary.

Good delineation is also obtained in the left side of the heart by direct injection into the pulmonary artery.

CASE 2. An 11-month-old white girl weighing 8.4 kilograms had had heart failure several times since a severe episode of vomiting and anorexia at the age of three months. She had never been cyanotic or dyspneic. The heart was very large, and the enlargement was preponderantly left ventricular. A tentative diagnosis of fibroelastosis was made, but it was felt that an anomalous coronary artery orifice, with or without an interventricular defect, could cause the same general symptoms. Upon catheterization of the heart, normal data were obtained. Since the chief interest was in the left side of the heart and since the foramen ovale was not entered, the catheter was placed in the main pulmonary artery and 10 cc. of 70 per cent Urokon was injected at a pressure of 2 kg. per cm. squared.* Exposures in two planes at the rate of six per second for one second were obtained. Exposure number 4 demonstrated the filling of the pulmonary artery. Exposure number 5, one ventricular systolic contraction later, showed the washing out of the pulmonary artery by the unopacified blood from the right ventricle.

During the pulmonary phase of the circulation, two exposures per second for three seconds were obtained. Then during the left heart circulation, six exposures per second for two seconds were studied. Film number ten showed the filling of the left atrium and of the pulmonary veins. The mitral valve was visualized. One atrial contraction later, in atrial systole, the atrial shadow was smaller. The valve was no longer visualized, and the opacified bolus was passing into the left ventricle. The twenty-second exposure of this series again showed the atrium in diastole with sharp delimitation in the region of the mitral valve. The left atrial appendage was well filled and appeared to be much narrower than is usually noted. The left ventricle (Figure 2, *left*) was again seen to be large and had not changed in size and shape since the previous study. Exposure number 24 (Figure 2, *right*) again demonstrated the identical situation in the left ventricle—the atrium in systole, the mitral valve open and the atrium contracted. It appeared as if the opacified blood was being forced through the immobile left ventricle by this very active left atrium. The diagnosis was endocardial fibroelastosis.

An even clearer delineation of the left-sided structures may be obtained with a direct injection into the left side of the heart. This can be done either through a patent foramen ovale, through a septal defect, or by direct percutaneous puncture with a long needle after the manner of Bjork.

*See footnote on page 162.

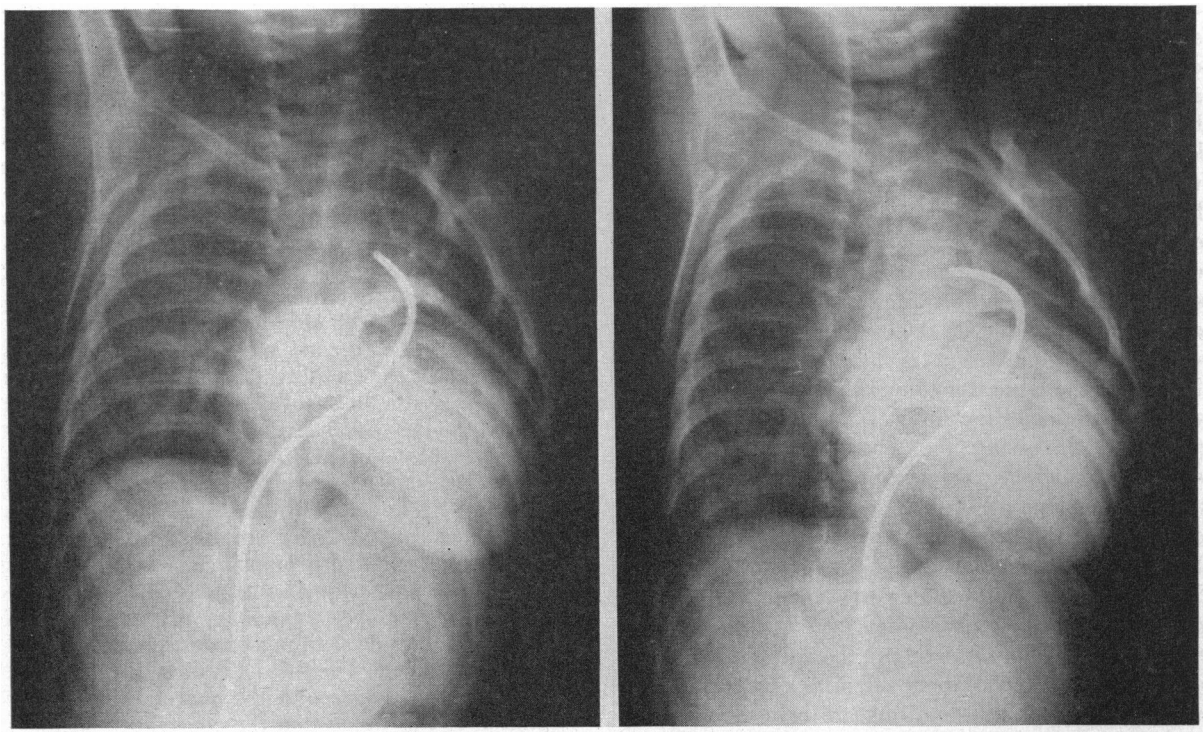

Figure 2 (Case 2).—Endocardial fibroelastosis. *Left:* The mitral valve is closed, the left atrium is filling. *Right:* Atrial contraction has filled the left ventricle, which has not itself changed in size.

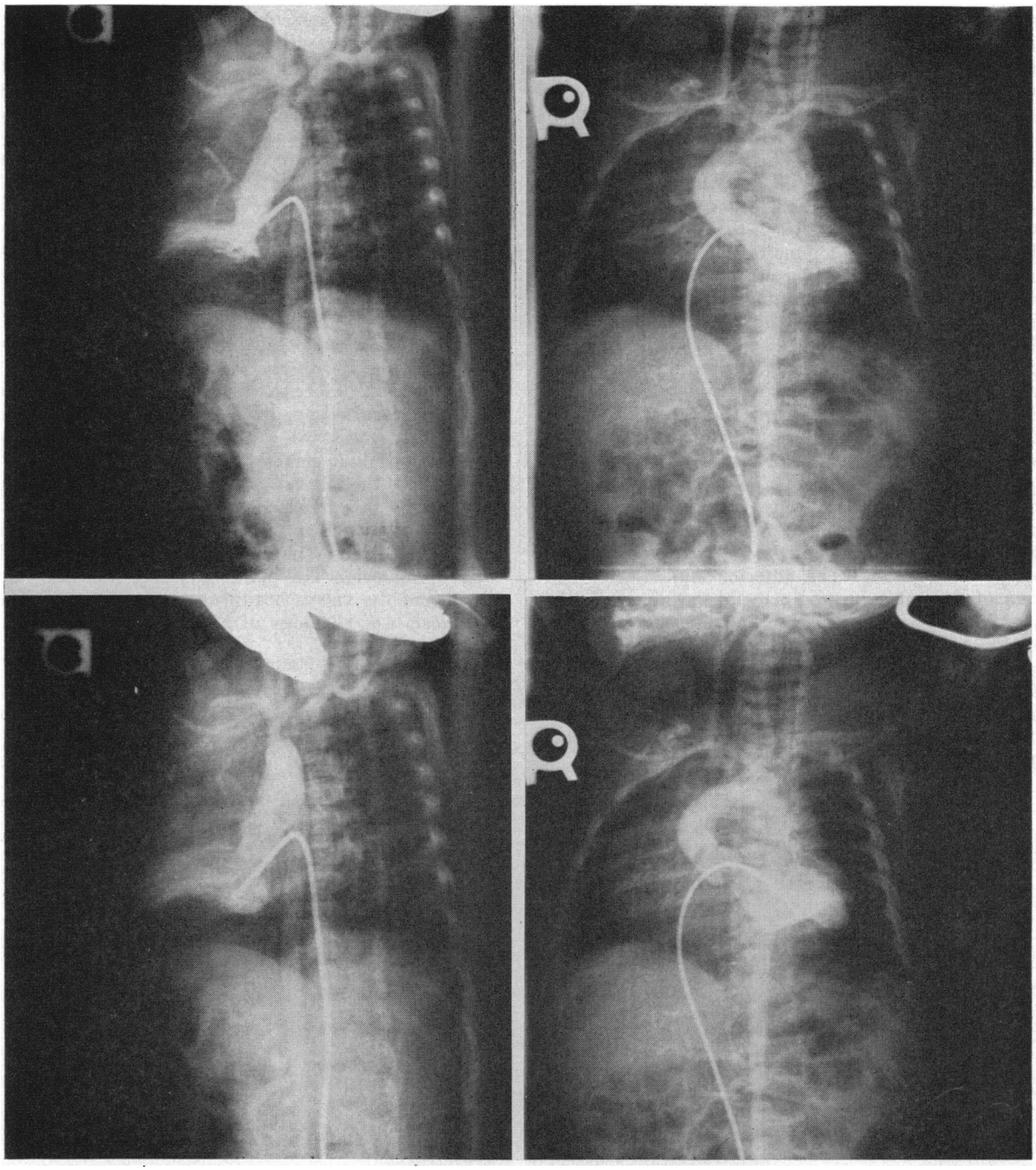

Figure 3 (Case 3).—Ebstein's anomaly with open foramen ovale. Simultaneous antero-posterior and lateral studies with catheter in the left ventricle. *Upper row:* Ventricular systole. *Lower row:* Ventricular diastole. Note the associated anomalies of the coronary arteries and of the subclavian-carotid complex.

CASE 3. The patient, a white girl four months of age, weighing six kilograms, had been cyanotic since birth. She was dyspneic and had frequent respiratory tract infections. She had had a cold three days before admittance, and one ear was reddened. The diagnosis at the time of admittance was "transposition of the great vessels." In conventional x-ray films the right atrium and right ventricle were noted to be quite large. Cardiac catheterization revealed a generally low oxygenation, and the catheterization impression was that the patient had pulmonic stenosis and an interatrial septal defect. The catheter was left in what was thought to be the right ventricle. Ten cubic centimeters of 70 per cent Urokon was injected under pressure of 1.5 kg. per cm. squared,* and the exposures were made at six films per second in two planes. Eight ven-

*See footnote on page 162.

tricular ectopic beats occurred immediately after the injection, but the rhythm soon returned to normal. The child was returned to the ward apparently unaffected by the examination. Film No. 9 showed the position of the catheter quite different from its site at the time of the insertion. Apparently in moving the child the catheter had been passed through the foramen ovale into the left atrium near its mitral orifice. This exposure was with the heart in diastole; the aortic valves were closed, the aorta had already been filled and its anomalous branches were observed arising from the arch. No innominate artery was present, and the left subclavian arose from the descending aorta as did the right subclavian, the latter crossing behind the esophagus. The coronary artery was noted to be also anomalous, a single large trunk ascending from the sinus and branching into its three components. There was great difference between the diameter of this coronary artery in diastole and the diameter in systole (Figure 3). The patient died the following day, apparently of respiratory failure. At autopsy the right atrium and right ventricle were huge. The foramen ovale was patent; the tricuspid valve was anomalous. Medial cusps were absent. The anterior and inferior leaflets of the valve formed a membrane from the tricuspid ring to the anterior and lateral wall of the ventricle. A separate blind pouch was present with papillary muscles attached to both sides of this membrane. In effect, then, there was a single chamber on the right side. The ductus was closed. Aspirated food and milk was present in the tracheal bronchial tree.

CASE 4. The patient, a five-year-old white boy, had been intermittently cyanotic since the age of six weeks. There was a history of squatting. A harsh systolic murmur with a thrill in the third interspace on the left was noted. A clinical diagnosis of infundibular stenosis was made, based chiefly on the cardiac configuration. Cardiac catheterization revealed evidence of both a right-to-left and left-to-right shunt as well as of right ventricular hypertension. The catheter could not be passed into the pulmonary artery and was left in the midportion of the right ventricle for subsequent angiocardiography. Although the patient weighed 17 kilograms, only 10 cc. of the opaque medium was injected. Exposures were made at a rate of 6 per second for three seconds and then 2 per second for six seconds in two planes. Before the first second (Figure 4) the injection revealed good filling of the right ventricle with enlargement of the crista supraventricularis and infundibular stenosis. A jet of opacified blood passed into the left ventricle. In ventricular diastole (Figure 5) this returned to the right ventricle with a jet of unopacified blood, and the infundibular chamber retained a moderate amount of the trapped opaque material. The pulmonary tree was well outlined and the valves beautifully demonstrated. The diagnosis was tetralogy of Fallot.

CASE 5. The patient, a boy 20 months of age, had had numerous episodes of heart failure since the age of five months and had had many upper respiratory tract infections. Interventricular defect was considered, and cardiac catheterization was

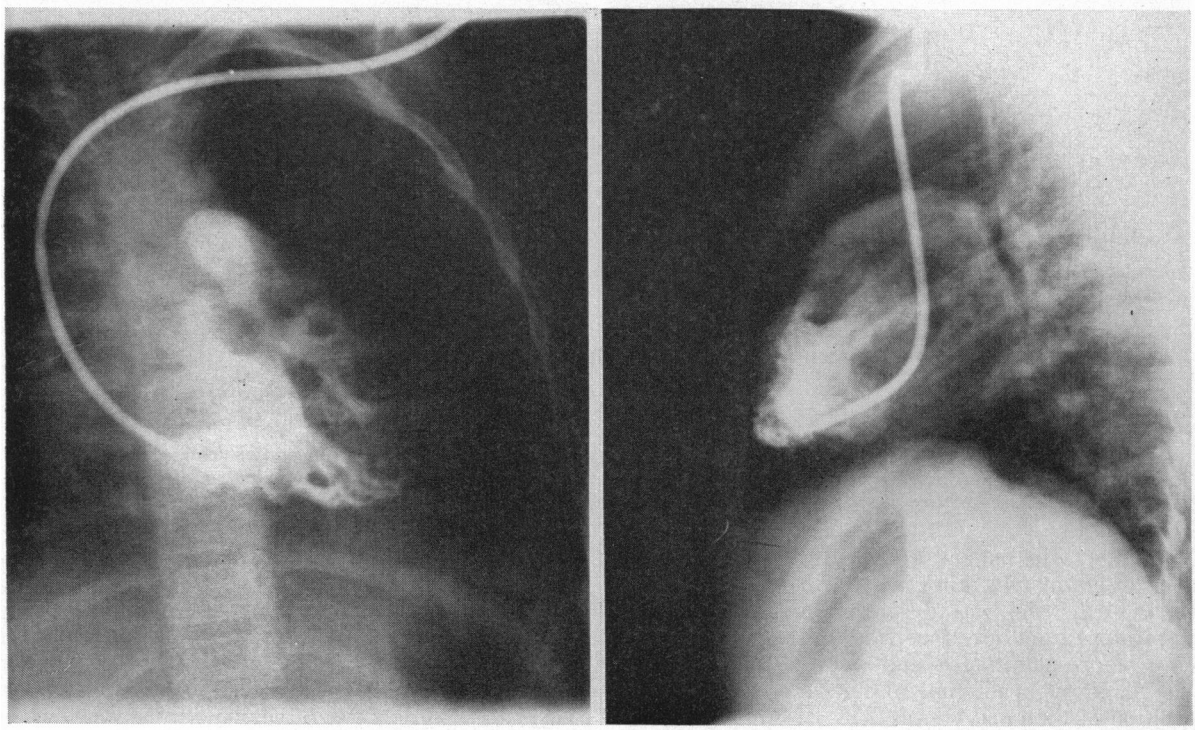

Figure 4 (Case 4).—Tetralogy of Fallot. Simultaneous exposures—large ventricular wall defect shown by transient reversal of shunt; catheter in right ventricle, pulmonic valves open.

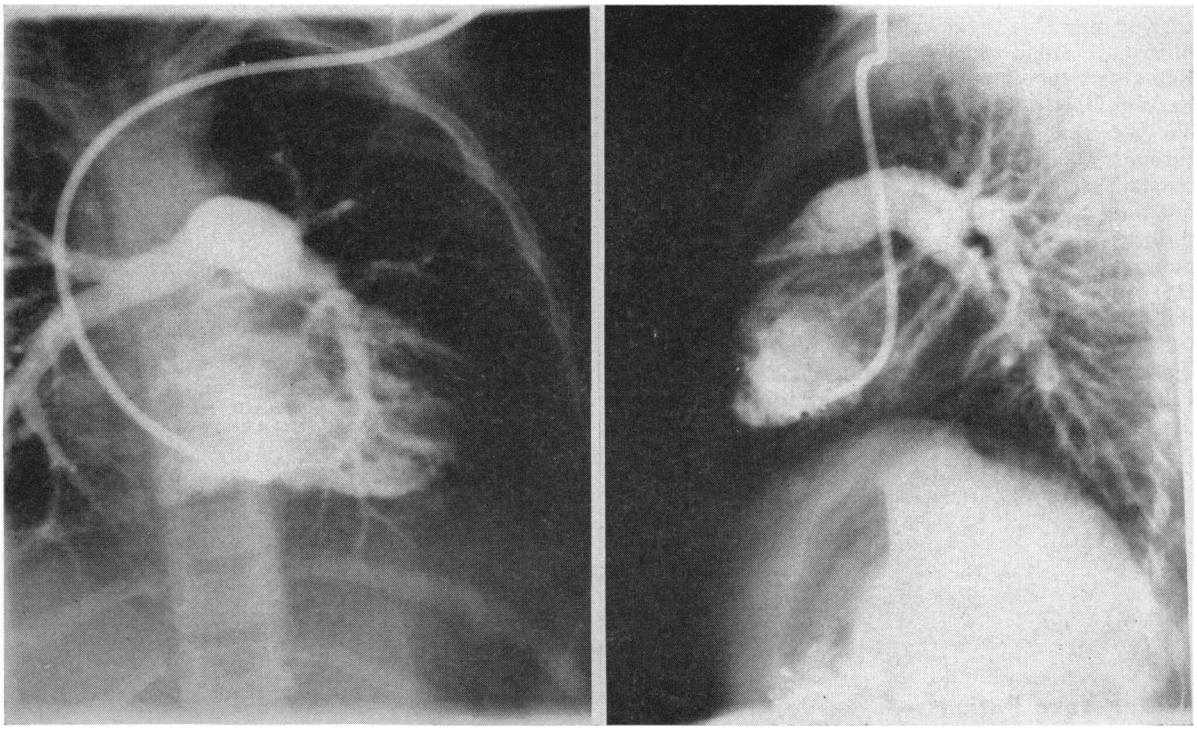

Figure 5 (Case 4).—Tetralogy of Fallot. Simultaneous exposures—pulmonary valves closed, one-tenth second later than Figure 4. Note the constant narrowing of the infundibulum of the right ventricle.

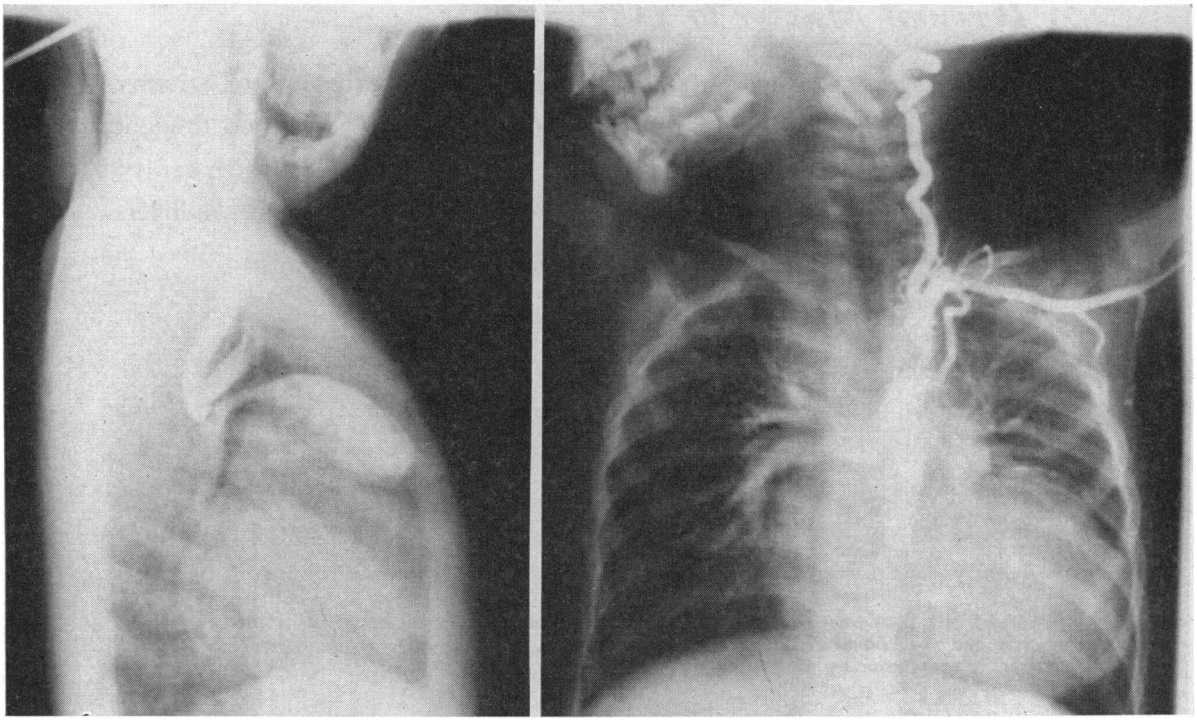

Figure 6 (Case 5).—Patent ductus arteriosus with coarctation of the aorta. *Left:* The aortic constriction is seen in the lateral projection at the attachment of the patent ductus arteriosus. Note the large pulmonary artery and its competent valves. *Right:* One-tenth second later the branch pulmonary arteries are well filled and the aortic collaterals are appearing.

carried out. This procedure demonstrated the probability of patent ductus arteriosus, possibly with reflux through the pulmonic valve into the pulmonary outflow tract. For angiocardiography, 8 cc. of 35 per cent Diodrast® was injected thereupon through a catheter in the left subclavian artery. At one-half second (Figure 6, *left*) the exposure showed not only the coarctation and the patent ductus arteriosus but also clearly demonstrated the distended pulmonary artery with its large competent valves. One-tenth of a second later (Figure 6, *right*) the pulmonary arteries extending out into the lung fields were well demonstrated and their relationship to the ductus arteriosus and the coarcted aorta was shown. Film No. 14, two seconds after the injection began, disclosed the retrograde flow of opacified blood from the internal mammary artery back to the distal portions of the aorta.* (It is tortuous vessels such as these that give rise to the intercostal pulse and the rib erosions which have become classical signs of coarctation of the aorta.)

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REFERENCES

1. Dotter, C. T., and Steinberg, I.: Angiocardiography, New York, Paul B. Hoeber and Company, Inc., 1951.

2. Kjellberg, S. R., Mannheimer, E., Rudhe, U., and Jonsson, B.: Diagnosis of Congenital Heart Diseases, Chicago, Yearbook Publishers, 1954.

*For details of operation in this case, see paper by Maloney and Flynn on page 173 of this issue of CALIFORNIA MEDICINE.